Question Number	Answer	Mark
1(a)	Increasing d will lead to a decrease in *C* **Or** see $Q/V = k/d$ **(1)** Since $C = Q/V$ (a decrease in *C*) means a decrease in the charge on the capacitor **Or** if *V* is constant (a decrease in *C*) means a decrease in charge on capacitor **(1)**	**2**
1(b)	Use of $C = k/d$ with $d = 4.2$ (mm) **(1)** use of $Q = CV$ *with* $V = 6$ V or cancelled later **(1)** use of $\Delta Q/Q$ or $\Delta C/C$ **(1)** % change = 17% **(1)** <u>Example of calculation</u> $Q = \frac{6\text{ V} \times 2.8\times10^{-15}\text{ F m}}{3.5\times10^{-3}\text{ m}} = 4.8\times10^{-12}$ C $Q = \frac{6\text{ V} \times 2.8\times10^{-15}\text{ F m}}{4.2\times10^{-3}\text{ m}} = 4.0\times10^{-12}$ C $\frac{4.8\times10^{-12}\text{ C} - 4.0\times10^{-12}\text{ C}}{4.8\times10^{-12}\text{ C}} = 16.7\%$	**4**
1(c)	(rapid changes in position) mean that rapid changes in Q **Or** a shorter time to charge/discharge **(1)** (small C gives) shorter <u>time constant/RC</u> **(1)**	**2**
	Total for question 13	**8**

Question Number	Answer	Mark
2(a)	Use of $C=Q/V$ **(1)** V= 15 V **(1)** Use of $W = QV/2$ **Or** $W = CV^2/2$ **Or** $W = Q^2/2C$ **(1)** $W = 2.5 \times 10^{-5}$ J **(1)** (candidates who use 6.6×10^{-6} C can only score MP1 and MP3) <u>Example of calculation</u> $V = Q/C = 3.3 \times 10^{-6}$ C / 220×10^{-9} F V= 15 V $W = QV/2 = (3.3 \times 10^{-6}$ C × 15 V)/2 $W = 2.5 \times 10^{-5}$ J	**4**
2(b)	$Q = 0.2\ Q_0$ **Or** $Q = 6.6\times 10^{-7}$ C **(1)** Use of $Q = Q_o\ e^{-t/RC}$ **(1)** t = 7.1 s **(1)** (candidates who use $Q = 0.8\ Q_0$ can only score MP2) <u>Example of calculation</u> $Q = 0.2\ Q_0$ $Q = Q_0\ e^{-t/RC}$ $0.2\ Q_0 = Q_0\ e^{-t/RC}$ ln (0.2) = - t/ ($20\times 10^6\ \Omega \times 220 \times 10^{-9}$ F) t = 7.1 s	**3**
2(c)	**Either** refers to $W = Q^2/2C$ **Or** $W \alpha Q^2$ **(1)** If Q halves, $W\rightarrow Q^2/8C$ Or halving Q quarters W **(1)** (Since W becomes a quarter in the time for Q to half) it takes less time for the energy to halve than the charge to halve. (dependent mark on either MP1 or MP2) **(1)** **Or** Refers to $W = QV/2$ **(1)** Q and V both decrease over time **(1)** W will decrease faster so takes less time to half in value. (dependent mark on either MP1 or MP2) **(1)**	**3**
2(d)	Synchronous readings **Or** data logger records readings at exact time **Or** voltmeter and stop watch need 2 people and data logger only one **(1)** More readings can be taken in a shorter time **Or** higher sampling rate **(1)** (treat as neutral any reference to graph plotting automatically, human reaction time or accuracy)	**2**
	Total for question 15	**12**

Question Number	Answer		Mark
3(a)(i)	Use of $Q = CV$ Q = 3900 (C) <u>Example of answer</u> Q = 1500 F × 2.6 V Q = 3900 C	**(1)** **(1)**	 **2**
3(a)(ii)	Straight line through the origin Passing through 2.6 V and answer to (a)(i) or 4000 C	**(1)** **(1)**	 **2**
3(a)(iii)	Use of $W = QV/2$ **Or** $W = CV^2/2$ **Or** use of area under graph W = 5.1 kJ (use of 4000 C gives W = 5.2 kJ (allow ecf from (a)(i)) <u>Example of answer</u> W = 3900 C × 2.6 V / 2 W = 5070 J	**(1)** **(1)**	 **2**
3(b)(i)	 Exponential decay Current decreases by equal fractions in equal time intervals	 **(1)** **(1)**	 **2**
3(b)(ii)	See attempt of I_0/e Finds time (accept 0.75-0.80s) Use of $\tau = RC$ R = 0.0005 Ω **Or** Finds the time for I_o to half Uses $t_{1/2} = \tau \ln 2$ Use of $\tau = RC$ R = 0.00050 – 0.00053 Ω **Or** See attempt of 37% of 5400 A Finds time (accept 0.75 to 0.80 s) Use of $\tau = RC$ R = 0.0005 – 0.00053Ω **Or** Draws tangent at t = 0 to meet time axis. Records intercept of tangent with axis (accept 0.6 s - 0.9 s) Use of $\tau = RC$ R = 0.0004 Ω – 0.0006 Ω **Or** reads a value off the y-axis and corresponding time Subs into formula using 5400 (A) to find RC Substitutes for C to find R R = 0.00050 Ω – 0.00058 Ω <u>Example of calculation</u> 37% of 5400 A is 1998 A Time to fall to this value is 0.75 s RC = 0.75 s R =0.75 s / 1500 F = 0.0005 Ω	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	 **4**

3(c)	**Max 3** Ultracapacitor used for: overtaking **Or** going up a hill **Or** starting (from rest) **Or** accelerating. **(1)** Because this requires a large <u>current/power</u>. **(1)** Batteries used for travelling at constant speed **(1)** Because this requires a small <u>current/power</u> for a longer time **(1)**	**3**
	Total for question 17	**15**

Question Number	Answer		Mark
4(a)(i)	Capacitor, resistor, supply and switch all in series (ignore voltmeter) Voltmeter directly across capacitor	**(1)** **(1)**	**2**
4(a)(ii)	Datalogger allows large number of readings to be taken **Or** graph can be plotted directly/automatically **Or** simultaneous reading of t and V can be taken **Or** idea that people can't record quickly enough, (treat as neutral accuracy, precision misreading or human reaction time)	**(1)**	**1**
4(b)	Use of $C = Q/V$ $Q = 5.0 \times 10^{-4}$ C Example of calculation $Q = 100 \times 10^{-6}$ F $\times$ 5.0 V $Q = 5.0 \times 10^{-4}$ C	**(1)** **(1)**	**2**
4(c)(i)	Use of $I = \Delta Q/\Delta t$ e.c.f their value of C from (b) I = 0.05 A (accept recalculation of Q using V = 4.90 or 4.95 V) Example of calculation $I = 5.0 \times 10^{-4}$ C / 10×10^{-3} s I = 0.05 A	**(1)** **(1)**	**2**
4(c)(ii)	tangent drawn at t = 0 $\Delta V/\Delta t$ = 2000 - 3300 V s^{-1} Initial current = 0.22 - 0.28 A (MP2 & 3 can be scored even if no tangent drawn) (No credit for exponential calculation) Example of calculation $\Delta V/\Delta t$ = 1.1 V/ 0.5 ms = 2200 V s^{-1} $I = (\Delta V/\Delta t) \times C$ I = 2200 V s^{-1} $\times 100 \times 10^{-6}$ F I = 0.22 A	**(1)** **(1)** **(1)**	**3**
4(c)(iii)	Use of $V = IR$ using answer from (ii) correct evaluation of R (5V used with current range in (ii) gives 18 - 23 Ω) Example of calculation 5 V = 0.22 A × R R = 23 Ω	**(1)** **(1)**	**2**
	Total for question 14		**12**

Question Number	Answer	Mark
5(a)(i)	Use of $t=RC$ **(1)** Use of $T=1/f$ **Or** $f = 1/t$ **(1)** Comparison of 2.2 x10^{-4} (s) << 2.5 x10^{-3} (s) **Or** comparison of 400 (Hz)<< 4500 (Hz) **Or** reference to nRC (needed for complete discharge) where n = 3 – 11 **Or** $e^{-T/t}$ is a very small value **(1)**	**3**
5(a)(ii)	See $C = Q/V$ **Or** $Q = CV$ **(1)** See $Q = It$ **(1)** See $t = 1/f$ **Or** $f=1/t$ **(1)** (Answers based on t = RC and V = IR scores 0)	**3**
5(a)(iii)	sub in $C = I/fV$ **(1)** C = 2.7 μF **(1)** <u>Example of calculation</u> $C = 5.4 \times 10^{-3}$ A/ (400 s^{-1} × 5.0 V) C = 2.7 μF	**2**
5(a)(iv)	2.2 + 30% = 2.9 (μF) **Or** shows that 2.7 (uF) is +22% of 2.2 (uF) **(1)** Within tolerance / consistent **(1)** (2nd mark can only be awarded following an attempt at either of the above calculations) If candidates make an error in (iii) allow full ecf with a valid comment based on their values.	**2**
5(b)	Use of ½ CV^2 **(1)** W = 3.4 × 10^{-5} J **(1)** (allow ecf from (iii) or use of 2.2 μF→2.75 × 10^{-5} J) <u>Example of calculation</u> W = ½ 2.7 μF × $(5.0\text{ V})^2$ W = 3.4 × 10^{-5} J	**2**
	Total for question 16	**12**

Question Number	Answer		Mark
6(a)	Method marks only Use of $Q=CV$ with $V=16$ V Max value of $C = 12000$ (μF) μF means 10^{-6} conversion of μF to F <u>Example of calculation</u> $C_{max} = 1.20 \times 10000 = 12000$ F $C_{max} = 12000$ F × 16 V $Q_{max} = 0.192$ C	 **(1)** **(1)** **(1)**	**3**
6(b)	Either use of ½ QV or ½ CV^2 Energy = 1.5 J <u>Example of calculation</u> W = ½ 0.192 C × 16 V Energy = 1.54 J	**(1)** **(1)**	**2**
	Total for question 13		**5**